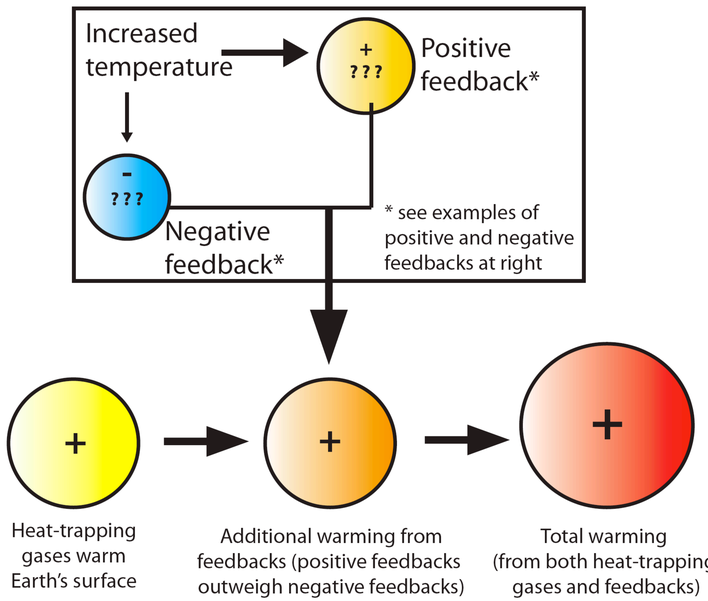
# Feedbacks Speed and Slow Climate Change

## FEEDBACKS IN CLIMATE SYSTEMS

As human activities increase the concentration of heat-trapping gases in the atmosphere, Earth's surface warms. This initial warming causes many changes in the atmosphere, on land, and at sea. These changes, in turn, may cause additional warming (positive feedbacks) or reduce the rate of warming (negative feedbacks). The actual rate of warming of Earth's surface is determined by the warming caused by heat-trapping gases, plus the effects of the feedbacks to this warming (see the figure below).

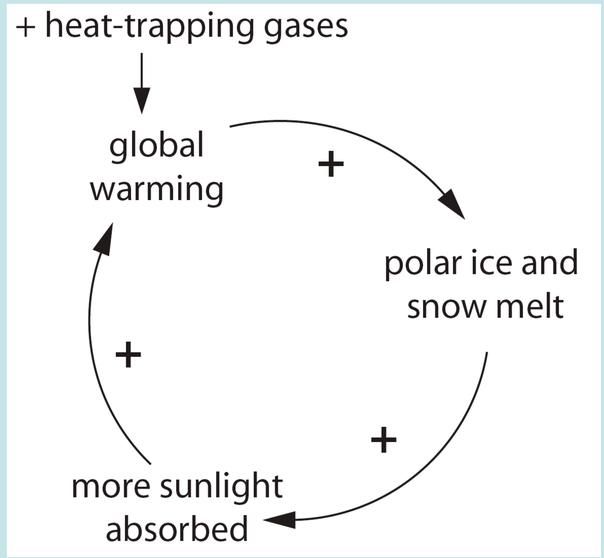



**Positive feedbacks to warming are expected to outweigh negative feedbacks, leading to additional warming. Scientists estimate that feedbacks may increase warming by 15 – 78% over this century.**

## POSITIVE FEEDBACKS

**Warming leads to positive feedbacks by:**

**Reducing ice and snow cover**, exposing soil or ocean water. Ice reflects much more solar radiation than soil or water. Loss of ice and snow means Earth's surface absorbs more energy, increasing global warming. See below.




**Increasing soil respiration rates** (see related display).

**Causing permafrost to melt**. Permafrost, the frozen soil commonly found in Earth's coldest regions, could release large amounts of $CO_2$ and methane if it thaws.

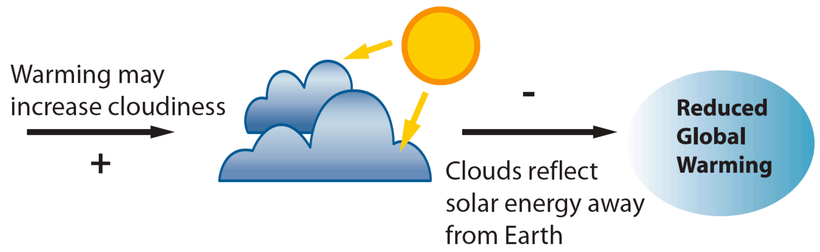
**Increasing water vapor concentrations.** Warmer weather leads to more evaporation. Water vapor is a powerful greenhouse gas.

**Positive feedbacks act to destabilize the climate system.**

## NEGATIVE FEEDBACKS

**Warming leads to negative feedbacks by:**

**Increasing cloud cover.** Warming leads to more evaporation, which can increase cloudiness. Clouds reflect solar radiation and decrease warming. However it is uncertain if cloud production will increase or decrease with warming. Overall, scientists believe that clouds will act as a negative feedback.




**Increasing plant growth.** As warming and increasing $CO_2$ stimulate plant growth, carbon storage on land may increase.

**Negative feedbacks act to stabilize the climate system.**

## IMPLICATIONS FOR FUTURE CLIMATE?

- ✓Feedbacks complicate predictions about future climate change.
- ✓We don't understand all potential feedbacks, if they will increase or decrease warming, or how long they will take to affect climate.
- ✓Because there are many positive feedbacks with delayed effects, scientists are concerned that we are underestimating warming that may occur in the future. Some of these feedbacks are not fully incorporated in climate models.


**References:**

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2. Gedney, N., Cox, P.M., and Huntingford, C. 2004. Climate feedback from methane emissions. Geophysical Research Letters 31.
3. Scheffer, M., Brovkin, V., Cox, P.M. 2006. Positive feedback between global warming and atmospheric $CO_2$ concentrations inferred from past climate change. Geophysical Research Letters 33.
4. Walter, K.M., Zimov , S.A., Chanton, J.P., et al. 2006. Methane bubbling from Siberian thaw lakes as a positive feedback to climate warming. Nature 443:71-75.



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